DEMONSTRATION OF WATER CONSERVATION THROUGH AUTOMATED DYEBATH REUSE

Beth White

AUTHOR: Student, Georgia Tech Research Institute, Georgia Institute of Technology, Atlanta, Georgia 30332-0837.
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Abstract. A system for automated dyebath reuse has been developed and demonstrated in a commercial dyeing facility. Results of the demonstration show that significant amounts of water, energy, and chemicals are conserved through dyebath reuse.

INTRODUCTION

The textile industry is a major consumer of water and energy resources and a major source of chemically-polluted wastewater (Clark, 1997). The batch dyeing process, used for dyeing many types of products, is especially wasteful. After each dye cycle, the spent dyebath is dumped down the drain. This process consumes excessive water, wastes the energy that is used to heat the baths, and releases dyes and other chemicals to the sewer. There is an opportunity to recover these baths and reuse them. However, the amount of residual dye in the spent baths is significant enough to lead to off-shade dyeings in subsequent batches if it is neglected. The concentrations of each component dye in the spent bath must be calculated, and the recipe for each reused bath adjusted accordingly.

BACKGROUND

Although dyebath reuse has been successfully performed on a plant-scale (Tincher, 1985) attempts at long-term commercial dyebath reuse have been discontinued due to the amount of human involvement required to analyze spent dyebaths (White, 1997). In order for the concentrations of residual dyes to be calculated quickly and accurately, the analysis process must be automated. A paper presented at the *1997 Georgia Water Resources Conference* (Clark, 1997) discussed the status of work performed at Georgia Tech in developing an automated system for dyebath reuse, and the modifications to the dyeing process which are necessary for dyebath reuse.

This automated dyebath analysis system is capable of determining residual dye concentrations in real time. The analysis system is linked to the plant's main computers, so that the amount of residual dye left in the bath is automatically subtracted from the recipe for the next batch.

In addition to an automated analysis system, a modified dyeing process also had to be developed. In conventional dyeing processes the baths are cooled at the end of the dye cycle by substantial dilution with fresh water to bring the carpet to a temperature acceptable for handling. In order to capture the energy, chemicals and dyes in a concentrated form when reusing dyebaths, a substantial amount of dyebath must be transferred from the beck at an elevated temperature before dilution cooling occurs. This is achieved by pumping most of the spent dyebath to a holding tank, then rinsing the carpet with cooling water. The rinse water remains in the beck, and the next carpet in the sequence is prerinsed with it. This carpet is dyed using the bath that was sent to the holding tank, after it is analyzed and reconstituted. The bath is pumped back to the beck while the bath is still hot. By capturing and reusing the bath while it is still hot, before it has been diluted, the maximum amount of energy and chemicals are reused.

Work on the automated analysis system and modified dyeing process has been completed, and the system has been installed at a carpet dyeing production facility in Dalton, GA. Using the modified dyeing process which was developed, three dyebath reuse trials were performed using both Nylon 6 and 66 carpets dyed a variety of shades.

RESULTS

The first trial was a non-automated two-carpet sequence for the purpose of testing equipment and establishing that carpet dyed with reused dyebath could meet the plant's quality standards. Both carpets in this trial were dyed successfully. The second dyebath reuse trial consisted of two series of carpets: a four-carpet series and a five-carpet series. The results are shown in Table 1. In the third trial, a series of five carpets were dyed. The results are shown in Table 2. Several of the carpets in the trials were initially off shade and required dye adds or redyeing. This is a very common practice in standard production. Plant personnel attributed the off-shade carpets in the trials to normal production variability and not any aspect of the dyebath reuse process.

Table 1. Results of Dyebath Reuse Trial 2

Reuse Run	Recovered Dye Qty. (grams)		Start Temp (F)	Energy Savings (MBTU)	Aux. Chem. Savings (lbs)
1a			Std.		
1b	Yellow	0	142	2.53	45.0
	Red	0			
	Blue	44			
1c	Yellow	0	135	2.31	60.9
	Red	0			
	Blue	99			
1d	Yellow	0	127	2.07	47.5
	Red	0			
	Blue	5			
2a			Std.		
2b	Yellow	0.2	137	2.38	41.8
	Red	0			
	Blue	0			
2c	Yellow	0.2	129	2.13	46.2
	Red	0			
	Blue	0			
2d	Yellow	0.2	135	2.32	46.8
	Red	0			
	Blue	0			
2e	Yellow	0.2	129	2.13	49.2
	Red	0			
	Blue	0			

Table 2. Results of Dyebath Reuse Trial 3

Reuse Run	Recovered Dye Qty. (grams)		Start Temp (F)	Energy Savings (MBTU)	Aux. Chem. Savings (lbs)
1a			Std.		
1b	Yellow	0	142	2.53	77.2
	Red	0			
	Blue	5			
1c	Yellow	0	139	2.44	43.2
	Red	35			
	Blue	85			
1d	Yellow	42	144	2.59	76.5
	Red	68			
	Blue	168			
1e	Yellow	68	132	2.22	62.4
	Red	70			
	Blue	215			

Water Savings

Approximately 3,700 of 6,000 gallons of dyebath are recovered and reused per batch of carpet. In addition to the water saved through reuse, less water is consumed in the cool-down and rinse cycle in the modified dyebath reuse process than in the cool-down portion of the conventional dyeing process. The conventional process uses 6,000 gallons of water for cooldown and rinse compared to 5,000 gallons for cooldown, rinse and prerinse in the reuse process. This represents a total water savings of approximately 39%. By using less water and discharging less water to the sewer, the demand on both the water resources and the waste treatment facilities is reduced.

Energy Savings

In the dyebath reuse demonstrations, the dyebaths were returned to the beck at an average temperature of 136F. Conventional dye cycles are started at the temperature of the supply water, which has a year-round average of approximately 60F in Dalton. Since the dyeings are started at an elevated temperature, less energy is required to heat the baths. The demonstrated energy savings are approximately 2.35 million BTU per batch.

Chemical Savings and Pollution Prevention

A significant amount of auxiliary chemicals are also saved in the reuse process. Throughout the dye cycle, most of the auxiliaries remain unchanged in the bath. In conventional dyeing, all of these chemicals are discharged to the sewer. However, a substantial amount of these chemicals can be recovered in the dyebath reuse process. In this demonstration, 70 percent of the auxiliaries were recovered, which is approximately 54.2 pounds per batch. Since these chemicals are quite expensive, reuse provides a significant economic benefit as well as reducing the amount of chemicals dumped to the sewer.

During the demonstration runs, preliminary information was gathered regarding the effects of dyebath reuse on effluent quality. Table 3 presents data on COD analysis results for samples collected at the end of standard and reuse dye cycles (prior to beginning cooldown) and at the end of the prerinse cycle of the dyebath reuse runs. The prerinse baths contain approximately 40% as many pounds of COD as a standard dyebath, indicating that a substantial portion of the COD loading comes from oils in the yarn finishes rather than from the dyeing chemicals. Although the COD level in the reused dyebaths tends to rise with each reuse, there is a tendency for this to level off after only a few cycles. Although COD concentration is higher in reused dyebaths, the volume of effluent is reduced, and the overall quantity of COD released to the sewer is decreased. The average amount of COD released per batch in standard production is 102.3 pounds. The average amount released per batch with dyebath reuse (including yarn oils removed in the prerinse) is 79.7 pounds.

CONCLUSIONS AND RECOMMENDATIONS

Automated dyebath reuse is an environmentally attractive process, which can save significant amounts of energy, water and chemicals that would otherwise be discharged to the sewer. Dyebath reuse also has strong economic benefits. Preliminary analysis of the savings achieved through dyebath reuse indicates expected cost reductions of approximately 2.9 cents per pound of carpet for nylon 6 fiber and 3.3 cents per pound for nylon 66 fiber. It is anticipated that these savings can be increased through process optimization.

Current work in this area includes the development of a commercial version of the prototype analysis system used in this project. Commercialization will enable the use of dyebath reuse technology to become widespread. Georgia Tech is currently beginning work with an industrial partner who wishes to have a commercial product on the market this year.

While the demonstration project has reduced the release of chemicals introduced in the dyeing process itself, it has not addressed the release of oils from fiber finishes on the carpet. In the modified dyeing process, the yarn oils are captured in a prerinse bath prior to dyeing. Since these oils are isolated from the other chemicals, there is an opportunity to remove them, reuse the water, and use the oils in some beneficial manner such as fuel blending. This opportunity warrants further investigation.

Table 3. COD Reduction With Dyebath Reuse

Run	COD (mg/L)	COD released (pounds)
Standard Production		
1	3000	149.0
2	1700	84.4
3	1800	89.4
4	2400	119.2
5	1400	69.5
Average	2060	102.3
Reuse Prerinses		
1a	1500	36.4
1b	1600	38.8
1c	2000	48.5
2b	1300	31.5
2c	1400	33.9
2d	2000	48.5
2e	1800	43.6
Average	1657	40.2
Reuse Dyebaths		
1a	1300	24.5
1b	2200	41.4
1c	2000	37.6
2b	2100	39.5
2c	2000	37.6
2d	2500	47.1
2e	2600	48.9
Average	2100	39.5

Finally, the technologies developed in this project can also be applied to a wide range of dye, fiber, and product combinations, not just the acid dyeing of nylon carpet. Automated dyebath reuse can be implemented in the batch dyeing of other textile products such as yarns and fabrics. Other water-soluble dyes such as direct, and basic dyes can be used with automated dyebath reuse on different types of fibers. Similar analysis procedures can be developed for non-soluble dyes, with the use of a solvent.

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